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ABSTRACT

Groups of red salmon bound for specific spawning grounds in the Kvichak River system, Alaska, were studied to determine the extent of their segregation during migration up the river. Spawning groups were found to be intermingled to the extent that they could not be managed independently through the application of differential fishing pressure.

INTRODUCTION

Bristol Bay, Alaska, derives its world-renowned red salmon *(Oncorhynchus nerka)* runs from five large and several small river systems which drain into it. The largest and most productive of these is the Kvichak.

The relative size of the important Bristol Bay river systems was reported by the U.S. Army Corps of Engineers (1957), and the following table lists several which will be mentioned in this report:

River system	Drainage area
	Square miles
Kvichak	7,700
Naknek	3,730
Alagnak	1,786
Egegik	2,740
Total	15,956

Note: Howard Donald Smith now with the Fisheries Research Board of Canada.

The location of each of these river systems is shown in figure 1. The highly productive Kvichak River includes Iliamna Lake, about 1,115 square miles in area, and Lake Clark, about 143 square miles.

Although the Kvichak River Salmon run is the most important in Bristol Bay, it is not possible to determine its precise economic worth because the catch is a composite of fish destined not only for the Kvichak but also for the neighboring Naknek, Alagnak, and Egegik Rivers.

The Egegik River empties seaward to the mouth of the other streams, but unpublished results of tagging experiments by the Fisheries Research Institute (FRI) of the University of Washington in 1947 and a report by the Bureau of Commercial Fisheries, Alaska Region, (1958) show that Egegik River fish sometimes account for as much as 8 percent of the Kvichak River catch. The Bureau report (p. 16) showed that of 9.672 fish tagged at the lower boundary of the Kvichak-Naknek fishing district, 3,414 were recovered by the end

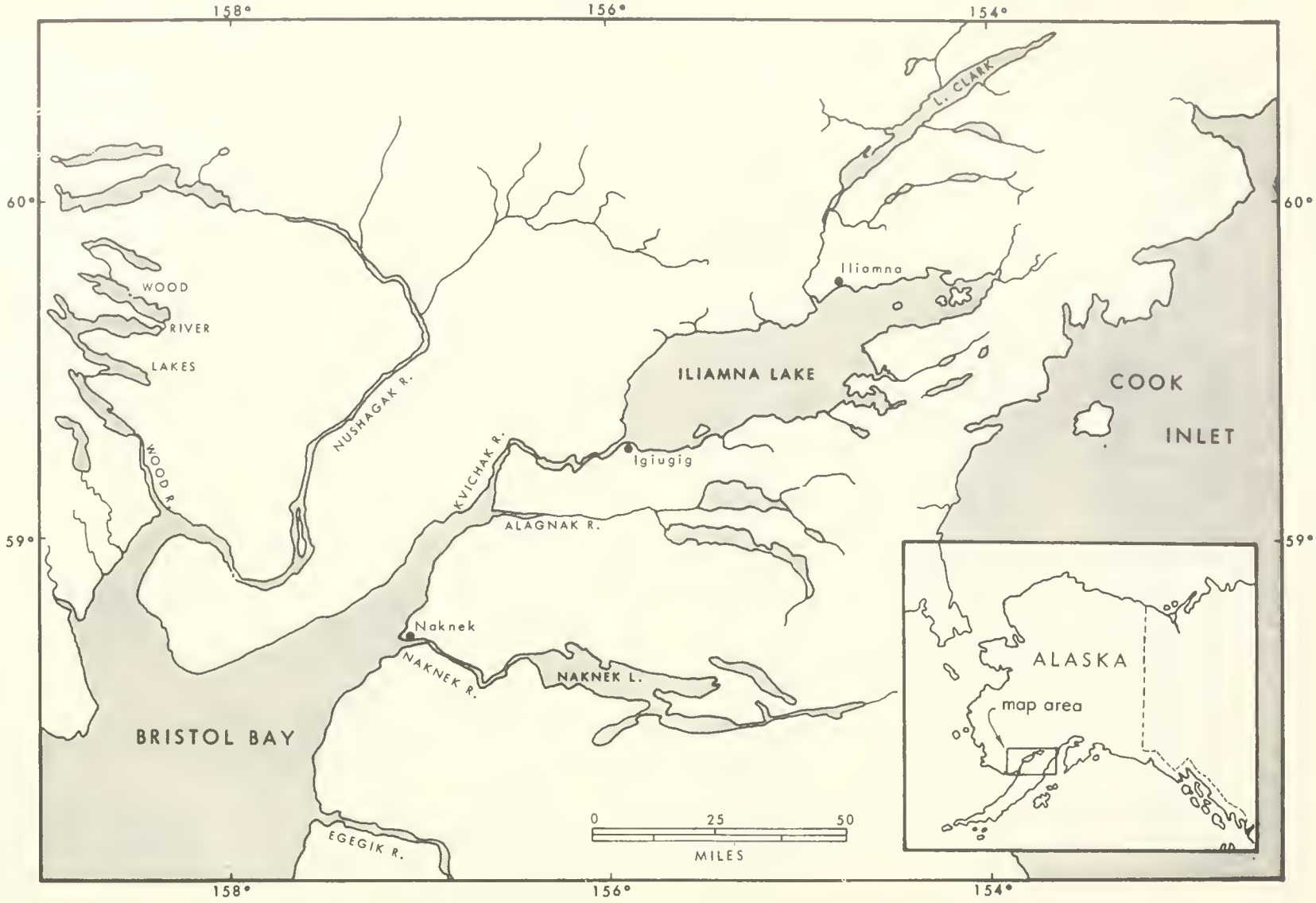


Figure 1.--Upper Bristol Bay and the Kvichak River Drainage.

of December from the Bristol Bay fishery. The Egegik River fishery accounted for 281 of these.

Counts of fish in the trunk streams show that the runs to the four river systems vary in relative size from year to year. Also, it seems likely that the extent of intermixture of the several runs is variable from year to year. Because of these considerations it is not easy to assess the economic worth of any one river by itself. In recent years escapements[1] have been counted on each of the rivers as an aid in determining the relative production of each. On the basis of these observations, about three-fourths of the fish in the Kvichak-Naknek catch are estimated to have been of Kvichak River origin. At current prices the average Kvichak-Naknek catch of the past 50 years would represent a $7.5 million annual income to fishermen.

When Kvichak River runs declined rapidly after the high production of the late 1930's (fig. 2), several Kvichak-Naknek salmon packers drafted a proposal to the U.S. Fish and Wildlife Service (FWS) in November 1954 expressing a need for a system of observations and research in the Kvichak River area similar to the work then being done on red salmon runs in the Wood River of the Nushagak River system. The Wood River work was done by FRI with funds provided by the Alaska Salmon Industry. Consequently, the contract, "Observations on Red Salmon in the Kvichak System," was entered into May 1, 1955, between the FWS and FRI. Field work started in May 1955.

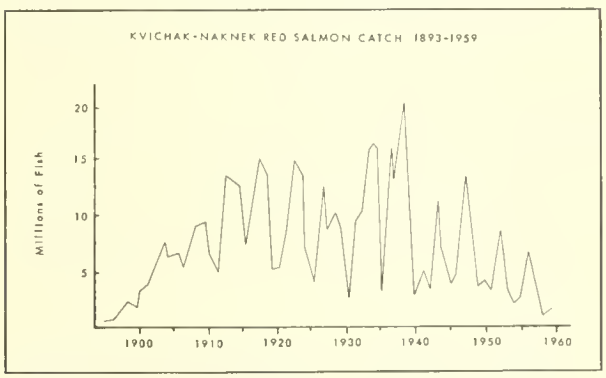


Figure 2.--Kvichak-Naknek red salmon catch, 1893-1959. Source: "Tabulated Information on the Red Salmon Runs in the Kvichak-Naknek District," Fisheries Research Institute unpublished manuscript, 1954 (revised 1956).

[1] "Escapement" is defined as that part of the run that escapes or evades the fishery and ascends the trunk stream.

The Kvichak program was to assemble facts useful for rehabilitating Kvichak River red salmon runs. The cause of the persistent decline in abundance was not known, but preliminary results from Wood River investigations indicated that basic physical and biological problems should be studied. Physical-biological investigations would encompass such matters as how freezing affects inadequately protected eggs in the gravel in winter and how low stream levels with attendant high water temperatures and intolerable low levels of dissolved oxygen in summer affect young salmon. Biological investigations would include studies of food supplies, spatial limitations, and predation by other species. From earlier investigations, it was apparent that population densities on the spawning grounds would have to be studied to provide information on optimum escapements. Finally, the intense fishery in Bristol Bay and the complicating effects of its selective gill net fishery would have to be understood.

Whatever the elements contributing to the decline in the runs, rehabilitation might be greatly simplified if groups of salmon bound for a well-defined spawning area, e.g., a tributary stream, a definite lake shore beach, or a connected unit of spring ponds, became segregated and thus recognizable in the fishery. If segregated, these spawning groups could be subjected to different levels of fishing pressure, and if desired, optimum levels of abundance for specified groups might be determined.

Spawning groups might be segregated in time or in space.[2]

[2] Some groups might also be recognizable by morphometric, morphological, serological, or other means, but these would not necessarily be segregated. Recognition of groups cannot be of value here unless different levels of fishing pressure can be brought to bear on them. Theoretically, there would still be a chance of selective action in the fishery if fish differed in size distribution from one group to the next. In that case, varying the sizes of meshes used in the commercial gill net fishery would vary the proportion from different groups in the catch. Evidence indicates that such differences in size are negligible.

Segregation in space can be dealt with in two parts. First, there is the possibility of segregation to areas that are unequally distant from the river mouth. This, it will be shown, is equivalent to segregation in time and therefore can be discussed under that heading. Second, there is the possibility of segregation along paths of migration at sea if spawning groups travel toward the river independently and merge only when they enter. There may be some tendency for the runs to each of the several rivers to favor certain lines of approach to their home streams, but segregation of whole river populations is far from complete, even at the mouths of these rivers; so it is most unlikely that there is segregation of their components in Kvichak Bay. Segregation of spawning groups in the area of the fishery is therefore considered negligible, and only segregation in time is discussed here.

Segregation in time might be expected. Though the entry of Kvichak River spawning groups into the streams is completed within a month, these groups spawn at widely different times. During the 3-month period July 25 to October 25 there is always some spawning activity in the system. Peak spawning is in August for some groups, in mid-October for others.

Spawning groups also spawn in at least three distinct types of locations as indicated by the FRI spawning ground enumerations of 1955-59, which accounted for 70 percent of the observed spawners in creeks and rivers, 25 percent on lakeshore beaches, and 5 percent in spring-fed ponds. In recent years substantial numbers of spawners have also been observed in deep water (Orrell and Demory, 1962). Spawning environments range from coffee-colored tundra streams in the lowlands, through clear, spring-fed waters in the foothills to milky, glacier-fed creeks and beaches in the mountainous regions. Spawning groups occupy each of these environments and it is probable that they may be separated genetically. Because timing of the spawning groups on the grounds differs enormously, the groups might have been segregated before their arrival.

Because it is in the fishery that the selective harvest must be undertaken, spawning groups must be identified there. In the Kvichak-Naknek fishery this identification is complicated by the intermingling of the runs to the several rivers, and at present it is not possible to determine positively to which system individual fish or groups of fish are bound. If identification is not possible by direct inspection in the fishery, the possibility remains of defining groups at some point within the river system and then back-plotting to determine the most probable time of passage of these groups through the area of the fishery. Such an approach is possible only in the event that the escapement and the run reflect a similar degree of segregation in time. Fortunately, available data show this to be true. First, it has been indicated (Bureau of Commercial Fisheries, 1958) that 55 percent of Kvichak River fish travel through the area of the fishery in 3 days or less after tagging. Second, when cumulative curves of abundance of salmon are plotted, one for the Kvichak-Naknek catch in Bristol Bay and one for the escapement at Igiugig on the upper Kvichak River, it is apparent that the time lag between modes of abundance in the fishery and modes of abundance at Igiugig is quite uniform. For the years 1955-58, the range was 5.7 to 10.4 days, with an average of about 8 days. From these data it appears that the chronological order of arrival of the fish in the fishery is preserved at least during their migration through the Kvichak River. Furthermore, it appears that extent of segregation of spawning groups in the escapement upriver reflects a similar segregation in the fishery.

The final step is to establish the extent to which recognizable spawning groups are segregated as they pass upriver. An experiment designed for this purpose was started in 1957.

METHODS AND MATERIALS

The escapement up the Kvichak River is estimated from counts made from towers located near the native village of Igiugig (fig. 1) below the outlet of Iliamna Lake. The fish are sampled by seine to determine age, size, and sex ratio as well as frequency of net scars and injuries. Records are complete for 1955-59.

Spawning groups would be completely segregated in time of escapement if they passed Igiugig one by one, but this is far from the case. More than 50 recognized spawning groups in the system pass through the Kvichak River within a 3- to 5-week period (Becker, 1962). If these groups could be sampled separately and their daily escapements plotted against time of passage, the resultant frequency curves would be found to overlap greatly. The extent of segregation of Kvichak spawning groups is therefore related to the degree of separation they exhibit if they can be plotted as described.

Unfortunately the degree of segregation cannot be determined by direct observation at Igiugig because individual fish are not identifiable as members of recognized spawning groups. Salmon, therefore, were tagged throughout the run at Igiugig and were recovered on the spawning grounds where segregation of spawning groups is more or less complete. Recoveries could then be related back to their time of passage at Igiugig. By this procedure the separation and sequence of spawning groups at Igiugig were postulated, and the feasibility of managing these groups in the fishery was evaluated. The underlying premise here is, of course, the homing tendency of particular stocks to particular spawning grounds (Thompson, 1959).

Capturing and Handling the Fish

Red salmon for tagging were captured in a beach seine fished from the shore of Iliamna Lake immediately above the outlet. When bad weather prevented lake shore seining, salmon were seined from the river. In 1959 the adult enumeration program at Igiugig was supplemented by assigning men to watch for salmon that had been tagged on the high seas. To provide a maximum recovery effort for tags sighted, the Igiugig seining was close to the observation points about a mile below the outlet of the lake. An electric shocker similar to the one described by Thompson (1960) was also used to recover tagged salmon.

Fish were generally captured at a rate of 30 to 35 per seine haul and were transferred to a holding bag beside the skiff. They were then transferred individually to a measuring trough lined with foam rubber. Tags were attached, scale samples taken, and length measurements and other pertinent data were obtained before the fish were permitted to continue their journey uplake.

Tags and Pins

The salmon were marked with Petersen tags. Nickel wire pins were used almost exclusively, but the point of attachment and size of the tag were not the same each year.

In 1957 white tags of 7/8-inch diameter were used, and a small 3/16-inch buffer tag was placed between the numbered tag and the head of the pin. This may have decreased loss caused by pins pulling through the tag, though no experimental control was used to test it. To relate live tagged salmon seen on the spawning grounds to time of tagging even though the fish were not recovered, the 1957 tags were placed in one of three positions under the dorsal fin: the leading edge, the middle section, or the trailing edge. This procedure did not prove useful, however, because the positions of the tags could seldom be positively identified while fish were in the water. Colored tags were not used in 1957 because the Bureau of Commercial Fisheries was using colored tags in Bristol Bay that year, and the presence on the spawning grounds of similar tags would have caused confusion.

In both 1958 and 1959, tags of 5/8-inch diameter were used. They were of four different colors and were applied in several color combinations of blank and numbered disks under the leading edge of the dorsal fin, the conventional point of attachment. All color combinations were readily distinguished on the spawning grounds, though combinations of red and white were found to be most readily seen under most conditions of water and lighting.

Rate of Tagging

Ideally tags would have been applied in proportion to daily escapements and throughout

the escapement period each year. All spawning groups would thereby receive tags in proportion to their size, and recoveries from days of tagging could be compared directly with the size of daily escapements. It was not possible to conform to this ideal design because escapement size and duration were largely unknown before the fish appeared.

The rate of tagging each year was as follows:

Year	Days of tagging	Tags attached	Escapement during tagging period	Ratio, tagged to untagged	
				Tagged	Untagged
	Number	*Number*	*Percent*		
1957	25	4,004	93	1	740
1958	14	2,276	97	1	235
1959	19	2,004	94	1	340

The tagging effort was distributed throughout each day so that periods of "no tagging" were as short as possible.

Tags were recovered by (1) field personnel of FRI, (2) local residents who fished salmon for their personal use, and (3) residents and visitors hunting or fishing in the region.

Personnel from FRI collected tags during routine population enumeration and size and age sampling on the spawning grounds. Recoveries were from both live and dead fish that were obtained usually with gaffs or spears. Personnel waded in the streams or stood in boats or on the pontoons of the plane. Tags were taken from live fish only when the fish were believed to have reached the stream or beach where they would spawn. In this way the danger of crediting fish of one spawning ground to spawning grounds occupied by another was minimized. Usually dead fish can be assumed to be on the grounds where they spawned, though they may drift and carry tags to other places.

In ponds and streams where fish could be seen readily tag recovery was relatively easy, but in large rivers and beaches where spawning took place in deep, swift, or turbid waters, recovery was frequently difficult. Recoveries from these sources were often at a low level. Moreover, beach spawners and transient fish often mingled briefly over the beaches. Since fish could not be assigned definitely to either stream or beach populations at such times, recovery effort was delayed until transient fish entered the streams.

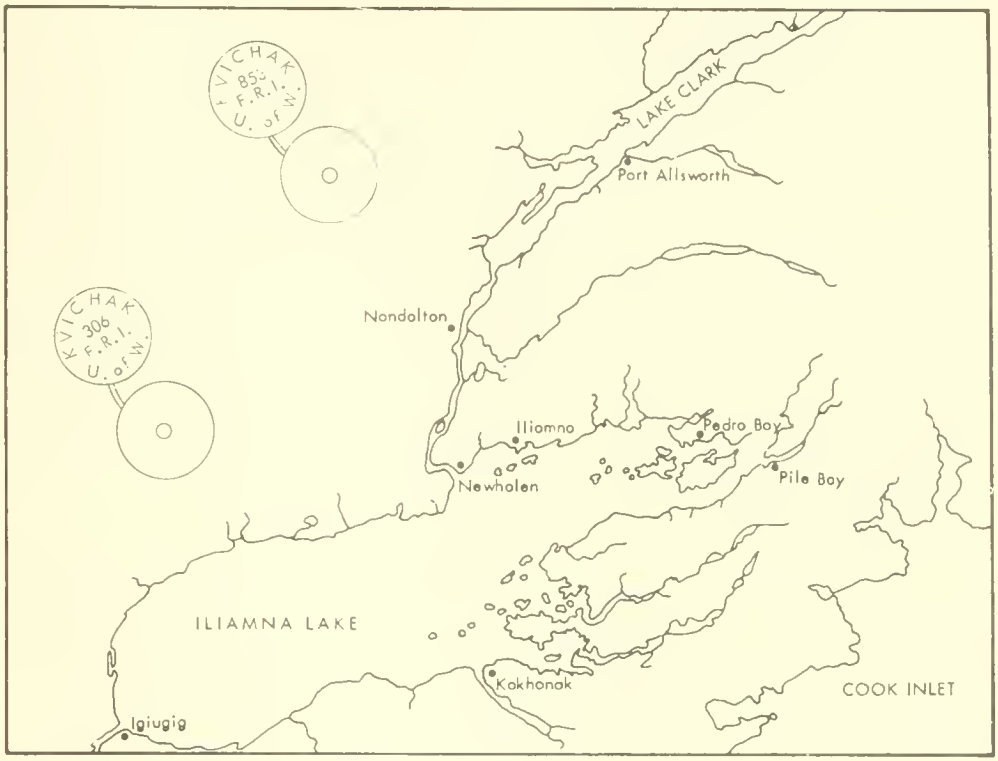
Personal-use fisheries accounted for 3 percent to well in excess of 10 percent of the total recoveries each year, as residents of native villages may take more than 100,000 fish annually. Personnel from FRI visited villages to pick up tags from the personal-use fishery and to encourage the native fishermen to record dates and locations where tags were taken. The recovery program was publicized in advance by mimeographed notices (fig. 3) circulated by mail and by members of the FRI staff.

Analysis

The relative segregation of spawning groups was shown by distribution of recoveries on the spawning grounds from each day of tagging at Igiugig. If salmon from each day's tagging were distributed on the spawning grounds in proportion to total numbers of spawning fish, segregation in time at Igiugig would be minimal. On the other hand, if salmon tagged each day went to different spawning grounds, segregation would be complete.

Proportions were studied in two ways: (1) By a visual comparison of all recoveries from days of tagging plotted on maps of the system and (2) by a statistical test of recoveries from days of tagging on major spawning grounds.

For the visual comparison, distributions of all recoveries from days of tagging were plotted by year and by experiment at recovery locations on maps of the spawning grounds.



The Fisheries Research Institute will tag several thousand red salmon at Igiugig again in 1959. Tags again will be colored.

Please help us as you did in 1957 and 1958 by returning tags and a piece of paper with the place the tagged fish was taken, and the month and day of the month it was taken. PLACE IS VERY IMPORTANT.

$1.00 (one dollar) will be paid for each numbered tag from this year's tagging. We still pay $1.00 tor 1958 tags too.

In September we will visit all villages and many private homes to pay cash for tags you have collected. If we miss you mail tags to:

KVICHAK SALMON STUDIES
FISHERIES RESEARCH INSTITUTE
UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON

We will mail you a check for tags sent in to us.

Figure 3.--Tagging advertisement used in 1959 to publicize recovery program in personal-use fisheries of Iliamna Lake and Lake Clark areas.

The relative segregation of the spawning groups was apparent from the similarity or dissimilarity of recovery proportions plotted in this way. Groups with substantial contrast could have been already segregated in time of occurrence at Igiugig and might require closer inspection.

For the statistical analysis, proportions could be readily arranged as contingency tables and tested for independence by the chi-square test. Recoveries from single days of tagging, however, were generally fewer than five in each recovery area. Consequently, recoveries were insufficient to permit tests on a day-to-day basis. Larger values had to be obtained by forming a few adequate units from the many inadequate recoveries from single days. To provide larger units all recoveries were incorporated into four approximately equal divisions of the tagging periods, giving four separate experiments annually. It is emphasized that the grouping into these experiments was an arbitrary one that was not anticipated when the studies began. Total days of tagging were not exactly divisible by 4 in any year. The remaining days, 1 in 1957, 2 in 1958, (one of which had no tagging), and 3 in 1959 (one of which had no tagging), were arbitrarily assigned to the fourth experiment. These additional days might have been apportioned to two or more periods in 1958 and 1959, but the final period in each of these years yielded a smaller number of recoveries than did any of the earlier periods. A more even distribution, and from the standpoint of the visual comparison at least, a more satisfactory block of data was formed in the manner described.

Tag recoveries from certain contiguous areas had to be consolidated. First, in certain areas recovery locations were reported vaguely. Usually this was because the pond or stream in question was but one of several unnamed ones in the area. Sometimes two or more streams drained an area of spring ponds, and it was difficult to associate spawning salmon with the stream they had ascended. In such instances no purpose would have been served by keeping small numbers of recoveries separate. It seemed better to consolidate them deliberately than to risk uncontrolled errors in the results and complication in the analysis by considering them separately. A second consolidation was sometimes necessary if recoveries were drawn wholly or in part from personal-use fisheries. The principal fisheries are concentrated on productive salmon streams, but the fishermen may fish wherever they can obtain the number of salmon they need. Except during times of shortage fishermen stay principally on historic sites, and any recoveries made in their vicinity may be reported as from those sites. It appeared best to describe the general areas of principal fisheries and to treat all recoveries from within those areas as units, bearing in mind the desirability of dealing as nearly as possible with well-defined spawning groups.

All recovery locations having consolidated data and the sources of their recoveries, e.g., streams and personal-use fisheries, are described below. The location and relative size of these areas, termed "collective recovery points," are shown in figure 4.

It is incorrect to consider consolidated recoveries as wholly representative of particular spawning groups because they include some tagged fish of unknown origin. Thus, all places of recovery are called recovery "points."

The collective recovery points and the sources of recoveries attributed to them are as follows:

1. GIBRALTAR: Gibraltar River, the personal-use fishery at the mouth, and the winter village 4 miles east.

2. SOUTHEAST BEACHES: Approximately 12 miles of beach area extending southwest from the mouth of Iliamna River and including the many small streams entering over the beaches.

3. PEDRO BAY: The personal-use fishery at Pedro Bay Village, Pedro Creek, and the small spring ponds near the village.

4. KNUTSON COMPLEX: The area bordered by Iliamna Lake from the head of Knutson Bay westward for 8 miles and the vigorous personal-use fishery at the mouth of Canyon Creek.

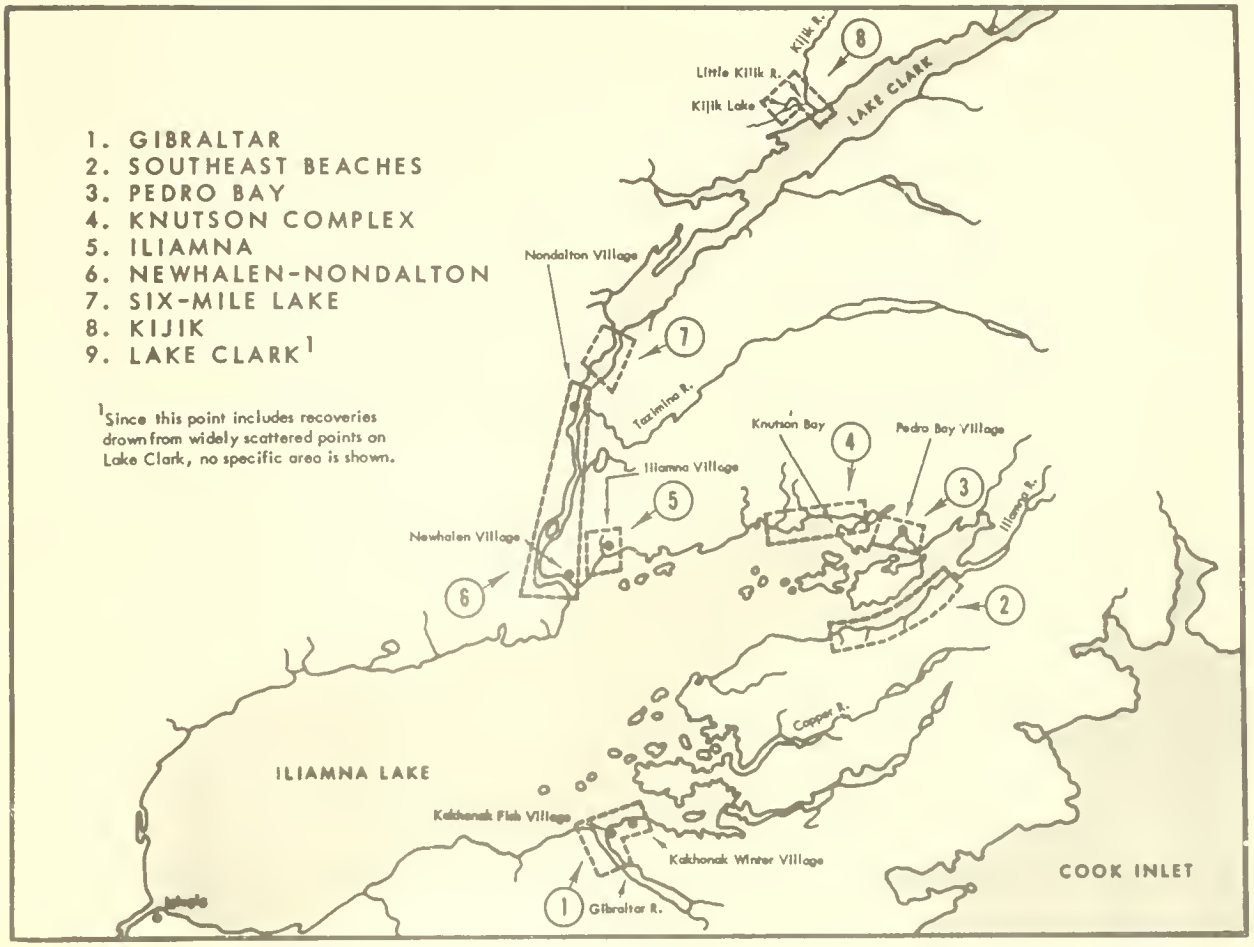


Figure 4.--Iliamna Lake and Lake Clark areas, showing collective recovery points.

5. ILIAMNA: Several minor spring ponds and streams within 5 miles of Iliamna Village.

6. NEWHALEN-NONDALTON: The entire Newhalen River and small streams tributary to it and the large personal-use fisheries at the villages of Newhalen and Nondalton.

7. SIX-MILE LAKE: All personal-use fisheries along the shores of the lake above Nondalton, but not including the Tazimina River.

8. KIJIK: Kijik Lake, its outlet stream, the Little Kijik River, and the main Kijik into which the latter flows.

9. LAKE CLARK: All Lake Clark recoveries that could not be associated with specific spawning grounds.

In addition to these collective recovery points, there are 19 representing isolated or largely isolated spawning groups.

To minimize the chance of failing to recognize segregated groups, it was important to test as many groups as possible. It was of greater importance, however, to test all groups having particularly large numbers of spawners. Not only would large groups be of greater economic importance, but they would, if segregated, provide better opportunity for management as a unit in Bristol Bay than would small, less conspicuous groups.

When all recoveries were in, most groups large enough to be useful in management were adequately represented either as isolated groups or as consolidations. On Iliamna Lake the points considered adequate were Gibraltar

River, Copper River (see figure 4 for location), Knutson Complex, and Iliamna River, though the Iliamna River had inadequate recoveries in 1957. These four areas received 70 to 80 percent of the spawning populations actually counted on Iliamna Lake from 1957 to 1959. Above Iliamna Lake, only the Newhalen-Nondalton recovery point was adequately represented each year, and it was tested with the Iliamna Lake points each year.

In addition to the separate recovery points mentioned, the two principal geographic divisions of the system, Iliamna Lake and Lake Clark, were compared. This provided a clue to the extent of segregation of spawning groups within the two lake systems and showed whether as units Iliamna Lake and Lake Clark fish were segregated in time of occurrence. If segregated, they might be independently manageable. In this comparison all recoveries in Newhalen River and above were considered to be bound for Lake Clark. Actually, some, particularly those recovered from Newhalen village, probably would have spawned in Newhalen River, but most were probably bound for Lake Clark.

In applying chi-square tests to these data, probability levels were interpreted in the conventional manner. Compared groups which yielded probability values less than $p=0.05$ were considered to have independent features and consequently to be segregated in time of occurrence at Igiugig.

RESULTS AND DISCUSSION

Recoveries from days of tagging in each of the 3 years are shown in tables 1, 2, and 3. Recovery points which include personal-use fisheries are footnoted, and consolidated recoveries appear as described in the list of collective recovery points, except in the case of Knutson Complex. There a breakdown was warranted because large numbers of recoveries were taken from one or more of the constituent groups each year. A few recoveries were received after the principal analyses were complete. They are grouped under an appropriate heading each year, but enter into one calculation only--the yearly recovery percentage.

The tagging results will be shown and discussed in the sections dealing with (1) the visual comparison and (2) the statistical analyses, but the import of the personal-use fishery in all these data warrants a section by itself. It was instrumental in raising the total recovery percentage from 6.9 percent in 1957 to 18.1 percent in 1958 and 18.3 percent in 1959. Our own recoveries meanwhile accounted for a relatively constant percentage: 3.2 percent in 1957, 4.1 percent in 1958, and 6.5 percent in 1959. The larger increase in 1959 was probably the result of improved knowledge of the spawning grounds of the system, or perhaps the result of improved tagging and handling techniques which resulted in fewer tag losses and tagging mortalities.

Effect of Personal-Use Fishery

Personal-use recovery data seldom differentiated between tags taken from fish captured for personal use and those taken incidentally, so it is not possible to give the exact recovery percentages of fish taken in nets. Nevertheless, personal-use recoveries rose from about 3.5 percent in 1957 to well in excess of 10 percent in 1958 and 1959.

Several factors were instrumental in increasing the percentage returns. In probable decreasing order of importance they are: (1) A smaller tagged to untagged ratio, (2) a better advertised tagging program, (3) better communication with fishermen, (4) greater familiarity with methods of handling tags and therefore greater effort to forward tags after the season ended, and (5) an increase in the reward offered from 50 cents per tag in 1957 to $1 per tag in the other 2 years.

Since personal-use fisheries contributed substantially to the total of recoveries each year, it is important that if inaccurate recovery locations are given or differential fishing effort exists, they are recognized as possible sources of error.

If recovery locations are incorrectly reported and a segregation of spawning groups in time materializes, bias will result. Many of the people who recovered these tags are

Table 1.--Distribution of 1957 recoveries from days of tagging, Kvichak River system

Day of tagging	Recovery location and number																					
	Belinda Creek	Dennis Creek	Gibraltar River[1]	Copper River	Nick G. Creek	Tommy River	Iliamna River[1]	Pile Bay[1]	Pedro Bay[1]	Knutson Bay[1]	Canyon Creek	Chekok Creek	Iliamna	Lower Talarik Creek	Newhalen-Nondalton[1]	Tazimina River	Six-Mile Lake[1]	Lake Clark(unspec)[1]	Tanalian Point	Kijik	Indefinite	All areas[1]
	1	2	3	9	10	11	13	14	16	18	19	21	22	23	24	25	26	27	28	30		
July 2			1	5	1						1				3							11
3		1		3			1	1		1	1				2					3		13
4	1		7	1				1					1		1				1	1		14
5				1											3			1		3		8
6			3	2			1				1											7
7			2	2						1					2	1				2		10
8			2	5							2			1	1							11
9			2	3		1				1												7
10		1	4	6							1				4		1					17
11	1		3	6													1					11
12			5	4			1			1		1			1	1						14
13			3	1	1																1	6
14	1		5								1		1		3							11
15			3	2		1						1			1					1		9
16	1		4	5	1				1		1											13
17	1		3	2						2	2				1					2		13
18			3					1			1											5
19			4	1											1							6
20			2	4			1		1		1		1									10
21	1		5	2	1	2	1			1					1							14
22			8	1			1		1	1						1			2			15
23			6	2		1	1			1					1			1				13
24	1		7	1	1					1					1							12
25	1		2	3						1	1				1			1				10
26			2	2		1									2							7
27			2	3											2					1		8
Total	8	2	88	67	5	6	7	3	3	11	13	2	3	1	31	3	2	3	3	13	1	[2] 275

[1] Recoveries in part or in whole known to be from personal-use fisheries.
[2] Does not include 24 tags recovered at or below Igiugig and 3 returned after analysis was completed.

semiliterate. Their understanding of the importance of accurate data is vague, and undoubtedly some of their records showing where tags were recovered are in error. It is not possible to determine the extent of errors of this sort, but certainly confusion was most likely between data from adjoining areas. Since these have generally been consolidated where confusion might arise, the remaining recoveries are believed to be insufficient to affect the data.

If fishing effort is not constant, the distributional pattern of recoveries can reflect effort and not, strictly speaking, abundance from each period of tagging. This, a more serious source of error, will occur if the chronological order of arrival at Igiugig is preserved at personal-use recovery points on the lakes, since tags should then be taken there in proportion to the daily abundance on days of tagging.

Certainly personal-use effort may vary in accordance with the need and the abundance of fish. Each family must catch a certain number of fish to satisfy winter requirements. If fish are plentiful needs may be satisfied early and effort will decline toward the end of the run, but if fish are not plentiful, effort may be intensified late in the season to make up the deficit. General fishing conditions, the amount of gear available, and the number of people

Table 2.--Distribution of 1958 recoveries from days of tagging, Kvichak River system

Day of tagging	Recovery location and number																											
	Gibraltar River[1]	Olympic Fish Village[1]	Granite Creek	Kakhonak River[1]	Alec Flyum Creek	Sawmill Bay[1]	Copper River	Nick G. Creek[1]	Tommy River	Southeast Beaches	Iliamna River[1]	Lonesome Bay	Pedro Bay[1]	Flat Islands	Knutson Bay[1]	Canyon Creek[1]	Tomkok Creek	Chekok Creek	Iliamna	Newhalen-Nondalton[1]	Tazimina River[1]	Six-Mile Lake[1]	Lake Clark (unspec)	Tanallian Point[1]	Mulberry Creek	Kijik[1]	All areas
	3	4	5	6	7	8	9	10	11	12	13	15	16	17	18	19	20	21	22	24	25	26	27	28	29	30	
July 7					1		1	3												7	1	2				6	21
8	[illegible]	1			1		7	3			3		5	3	2	1	3	1		22	1		4		3	4	74
9	2[illegible]	3	1		1		4		2		6		3	5	4	2	2			19	1	1	5	3		2	86
10	1	1		1			2	1		1	3				1	4	1			12	1	1			1		31
11	[illegible]						2			4	2		2	2	1					11			3	1			34
12											1								1								2
13	3	1		2			1									1				4							12
14	1										1									1						1	4
15	11	4	1	1	2	1	4	1	1	1	6	1	2	5	2	2	2		1	29	2		7	2	1	3	92
16	12	1			1					1	4		1			1	1			17			4	3	2	1	49
17	2																								1		3
18											1																1
20											1									1						1	3
Total	68	11	2	4	6	1	21	8	3	7	28	1	13	15	10	11	9	1	2	123	6	4	23	9	8	18	[2]412

[1] Recoveries in part or in whole known to be from personal-use fisheries.
[2] Does not include 14 tags recovered at or below Igiugig, and 1 after analysis was completed.

fishing can influence fishing effort just as they do in a commercial operation. Possible variation in total recovery effort can be evaluated however. Since personal-use fishing is the principal source of recoveries, total effort and personal-use effort will be similarly distributed. If the chronological order of passage is maintained at personal-use fishing locations, and there is inequality in effort, different periods of tagging will yield different recovery percentages. For instance, if fish tagged in two consecutive periods pass up the lake as units and several days apart, a fishery operating when the first unit passes but not when the second passes may produce tags from the first period's tagging but cannot produce tags from the second. Clearly the percentages recovered from each unit cannot be the same, under such conditions.

In table 4, the fish tagged and tags recovered are shown as total numbers and percentages each year. Further breakdown within years shows the number of tags by experiment and the tagged and recovered fish in each experiment as a percentage of the seasonal total. Apparently the percentage of total tagged in each experiment each year was remarkably close to the percentage of total recovered in each. On the basis of these somewhat similar percentages, it would appear that the effort in personal-use fisheries was quite evenly distributed over all of the groups tagged during the years studied.

One may also be concerned about variation in fishing effort if the chronological order of passage was not maintained at personal-use fishing sites. In that event the effect would not be detected but it is inconsequential, since the analysis for extent of segregation would not then be biased by a changing fishing intensity. Complete intermixture would result in a random exposure of all tags to any pattern of fish effort.

It appears that, despite the hazards of unlimited utilization of personal-use recoveries, they should not have introduced troublesome errors in the analysis.

Visual Comparison at All Recovery Points

Recoveries are plotted for the 3 years on figures 5, 6, and 7 to illustrate the overall pattern of distribution each year. The exact locations of the recovery points are shown in figure 8.

Table 3.--Distribution of 1959 recoveries from days of tagging, Kvichak River system

Day of tagging	Recovery location and number																							
	Belinda Creek	Gibraltar River[1]	Olympic Fish Vill.[1]	Copper River	Nick G. Creek[1]	Tommy River	Southeast Beaches	Iliamna River[1]	Pedro Bay[1]	Flat Islands	Knutson Bay[1]	Canyon Creek[1]	Tomkok Creek	Chekok Creek	Iliamna	Lower Talarik Creek	Newhalen-Nondalton[1]	Tazimina River[1]	Six-Mile Lake[1]	Tanalian Point[1]	Kijik[1]	Chulitna River[1]	Indefinite	All areas
	1	3	4	9	10	11	12	13	16	17	18	19	20	21	22	23	24	25	26	28	30	31		
July 4								2						1			4							7
5		1	1	3				1						3	1		6		2					18
6		1		2	1			2	1			2	1	3			6					1		20
7		7		8	1			1	1	2		1		2			11		1	1				36
8				4				3						1			8		1		1			18
9		3	1	2				1	2			1		1		2	6					2		21
10		5		10	1			3	3		1	2		4			9				4		1	43
11		6		2				4	1	3				3	2	3	7				3			34
12				1				1	1	1						1								5
13	1	4	1	8			1	2	2	3							8		2		1			33
14		4	1	1				4	1			1	1	1			11							25
15		4	1	6		1		3	4		1	1		2	1	2	8	1	1		2	3		41
16		6		2	1		1		1								8		1					20
17		3		1	1			1		1	1			3			2				1			14
18				2				1		1				1			1							6
19				1		1								1										3
21				1				1																2
22				1				1																2
Total	1	44	5	55	5	2	2	31	17	11	3	8	2	26	4	8	95	1	8	1	12	6	1	[2]348

[1] Recoveries in part or in whole known to be from personal-use fisheries.
[2] Does not include 22 tags recovered at or below Igiugig and 18 recovered after analysis was completed.

The evaluation of the data shown on the three maps is necessarily subjective, and it is suggested that the reader consider each year's data in two steps as follows: First, compare the distribution at each recovery point against the composite. Distributions that contrast with the composite may reflect independent timing and may be segregated. To consider such distributions further, and because certain composites are heavily weighted from principal recovery points a second step is necessary. Second, therefore, take particular distributions that are like the composites and compare them with distributions which have suggested a segregated spawning group. If groups appear to contrast both with the composite and with distributions like the composite, then segregation appears likely.

Using this two-step analysis, it is possible to consider the likelihood of segregated groups in the 3 years with tagging data.

In 1957 the same number of fish were tagged in each experiment (table 4). Figure 6 shows that approximately the same number of recoveries were derived from each composite. Comparing the individual points with this, Kijik Lake (No. 30) is clearly contrasted. Newhalen-Nondalton (No. 24) and Gibraltar (No. 3) are both somewhat in contrast. All other recovery points conform to the pattern or are too poorly represented to be significant. The three points in contrast with the composite also appear to contrast with other particular recovery points.

Table 4.--Summary of red salmon tagging experiments, Kvichak River system

Day of tagging	1957						1958						1959					
	Experiment number	Fish tagged	Total fish in each experiment				Experiment number	Fish tagged	Total fish in each experiment				Experiment number	Fish tagged	Total fish in each experiment			
			Tagged		Returned				Tagged		Returned				Tagged		Returned	
		No.	No.	%	No.	%		No.	No.	%	No.	%		No.	No.	%	No.	%
July 2		160																
3		160																
4	1	160	1,000	25.0	66	24.0								28				
5		160											1	132	436	21.8	82	23.6
6		160												127				
7		160						102						149				
8[1]		160					1	381	978	42.9	181	43.9		143				
9		117						495					2	125	613	30.6	115	33.0
10		201						196						188				
11	2	160	1,000	25.0	68	24.7	2	208	419	18.4	67	16.3		157				
12		160						15						33				
13		160						76					3	192	638	31.8	104	29.9
14[1]		160					3	47	527	23.2	108	26.2		162				
15		160						404						251				
16		160						277						131				
17	3	160	1,000	25.0	58	21.1		18						79				
18		160					4	13	352	15.5	56	13.6		37				
19		160						0					4	36	317	15.8	47	13.5
20[1]		160						44						0				
21		160												25				
22		160												9				
23		140																
24	4	140	1,004	25.0	83	30.2												
25		140																
26		120																
27		106																
Total		4,004			275	100.00		2,276			412	100.00		2,004			348	100.00
Late recoveries					3						1						18	
Grand total					278						413						366	
Total recovery percentage					6.9						18.1						18.3	

[1] 1957 experiments overlapped on these dates.

In 1958 about twice as many fish were tagged in experiment 1 as in any of the other three. Figure 6 shows that the composite reflects this, i.e., nearly twice as many recoveries were derived from experiment 1 as from any of the others. In 1958 Kijik Lake was again in contrast with the composite, though the pattern of high and low numbers of recoveries per experiment was preserved. No other recovery points appeared to contrast significantly.

In 1959 (fig. 7) most of the tags were put on in experiments 2 and 3, and once again the return was significantly higher from these than from experiments 1 and 4. For the third time the Kijik Lake distribution was in contrast with the composite and for the third year failed to have representation in all four experiments. Lower Talarik Creek (No. 23) was represented by eight recoveries, all lumped in experiments 2 and 3. The distributional pattern of the composite was clearly preserved, however, so the recovery point does not appear significantly discrepant.

In summary of the 3 years' data, it appears that only Gibraltar River, Newhalen-Nondalton, and Kijik are notably in contrast with the composites. Kijik is obviously the most consistently aberrant recovery point, tending to have fewer late-run fish. The other two contrasted most in 1957, though Gibraltar received a slightly higher number of late-run fish, and Newhalen-Nondalton a slightly higher number of early-run fish in all 3 years. All three of these recovery points will be considered further in the statistical analysis.

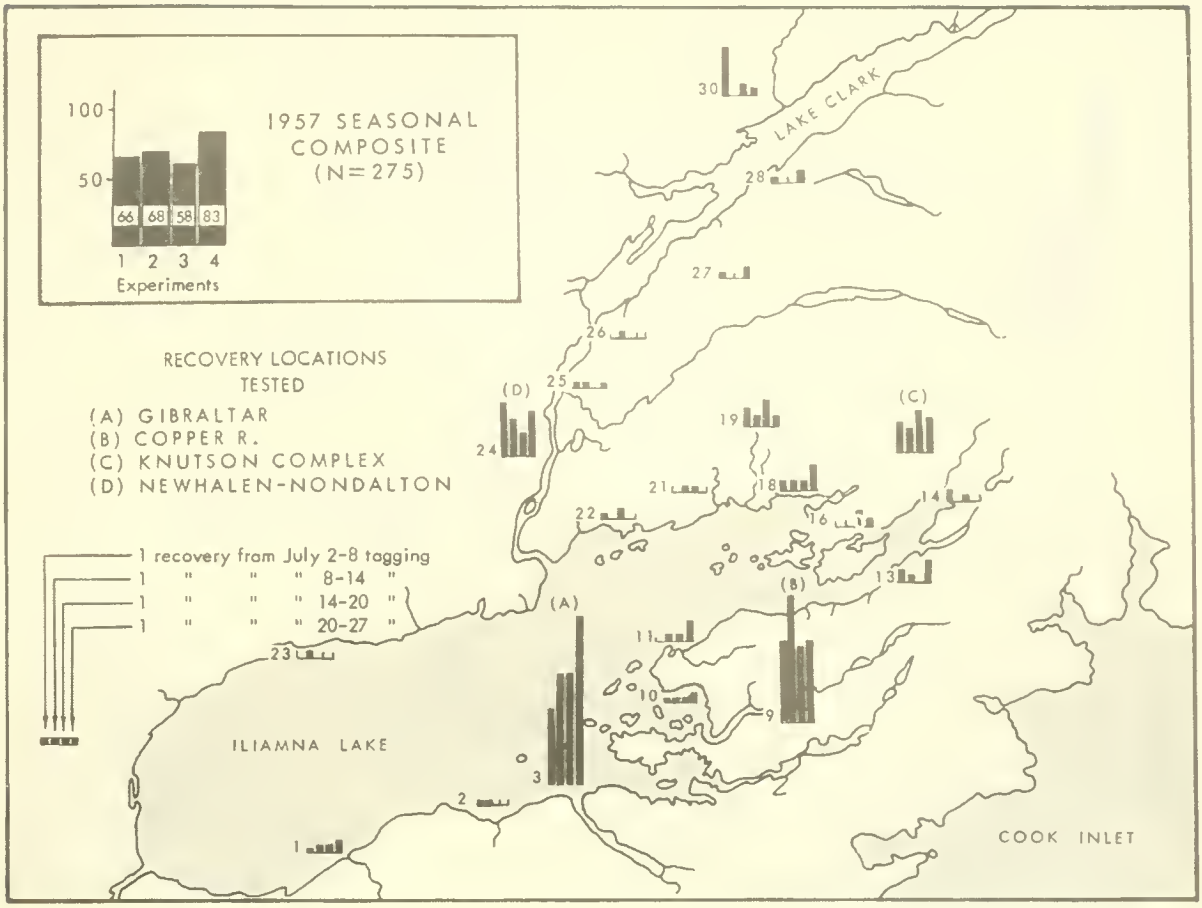


Figure 5.--Recoveries by experiment, 1957, Kvichak River system. The combined recoveries from all experiments are plotted as a bar graph in the box labeled "seasonal composite." Recovery distributions at the individual points are plotted as bar graphs and are shown at the appropriate locations on the map (numbers on abscissa are from tables 1, 2, or 3). Recovery distributions to be compared statistically are identified by a letter above the graph that corresponds to the name in the sequence on the lefthand margin. (See figure 8 for locations of recovery points.)

Statistical Comparison for Principal Recovery Points

The statistical tests are an objective approach to showing whether segregation does or does not exist. It is particularly important that numerically large spawning groups be tested in this way, for they can play an important part in the management of the fishery if they are segregated.

Recoveries from each of the important recovery points are arranged in table 5 by experiment, except for experiments 3 and 4 which are combined in 1958. In that year experiment 4 was not sufficiently represented for a test in the preferred manner.

Chi-square tests of the hypothesis of like recovery distributions among four recovery points in 1957 and five recovery points in each of 1958 and 1959 gave values $p=0.203$, $p = 0.400$, and $p = 0.929$ respectively. It is significant that the high levels of p in 1958 and 1959 are associated with the strongest tests, i.e., more areas tested and greater numbers of recoveries. Since the values of p are high in all 3 years, segregation in time of passage at Igiugig is probably minimal. It is important, however, to consider whether these recoveries are representative of the single spawning groups (as defined) utilizing specific spawning grounds.

On Copper and Iliamna Rivers the recoveries are surely representative of those systems.

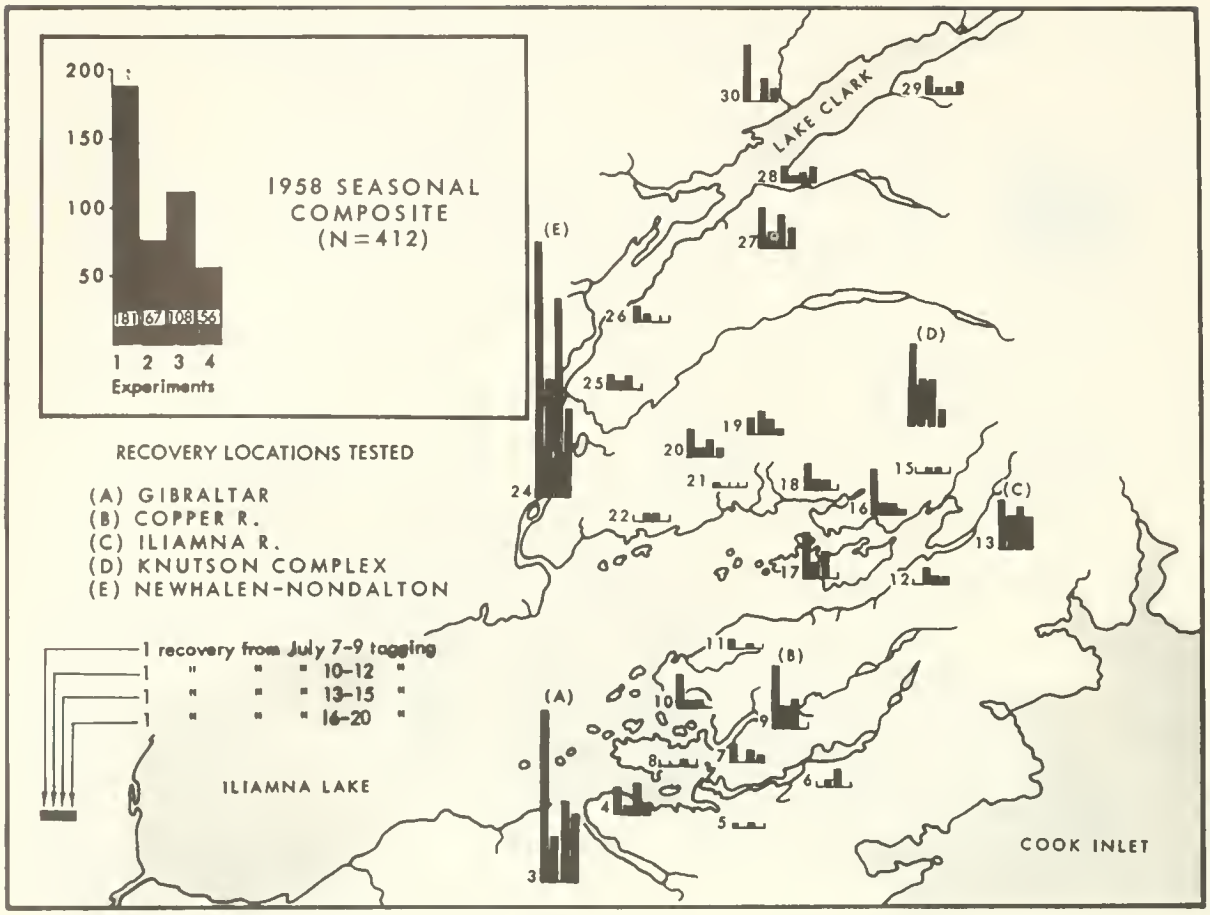


Figure 6.--Recoveries by experiment, 1958, Kvichak River system. For explanation of figure, see legend to figure 5.

Copper River recoveries were virtually all made by FRI personnel during stream surveys well above the river mouth; Iliamna River recoveries by FRI personnel and by personal-use fishermen. Iliamna River is geographically isolated, and personal-use fishing is conducted well inside the river so there should have been little doubt of the destination of tagged fish taken there.

Gibraltar River recoveries are primarily from personal-use fishing. A well-defined bar runs across the river mouth and parallels the beach for about half a mile, and most personal-use fishing is conducted well inside this. Tags taken in this fishery are primarily from Gilbraltar River fish. Occasional tags were reported to have been caught at the winter village, but since there is only a small and erratic fishery there, it is safe to assume that Gibraltar tags were predominantly "fish village" recoveries.

Knutson Complex recoveries were dra from a beach spawning area extending about 8 miles along the north side of Knut Bay and from four streams. Two of the strea enter Knutson Bay in the beach spawning ar and two enter immediately adjacent to the w end of the bay. It is impractical to differenti recoveries from within the Knutson Compl First, there is an array of spring pond and s channels bordering the two major streams the west end of the bay. The streams dr separate mountain valleys, but unite to forr single channel as they cross the tundra. N the beach the single channel splits again, two widely separated streams finally discha into Iliamna Lake. Salmon may enter so of the spring ponds and channels thro either or both of the streams. Second, a ma source of Knutson Bay recoveries is a sn but vigorous personal-use fishery in the w end of the bay. This catches fish from b beach and stream groups in the immedi

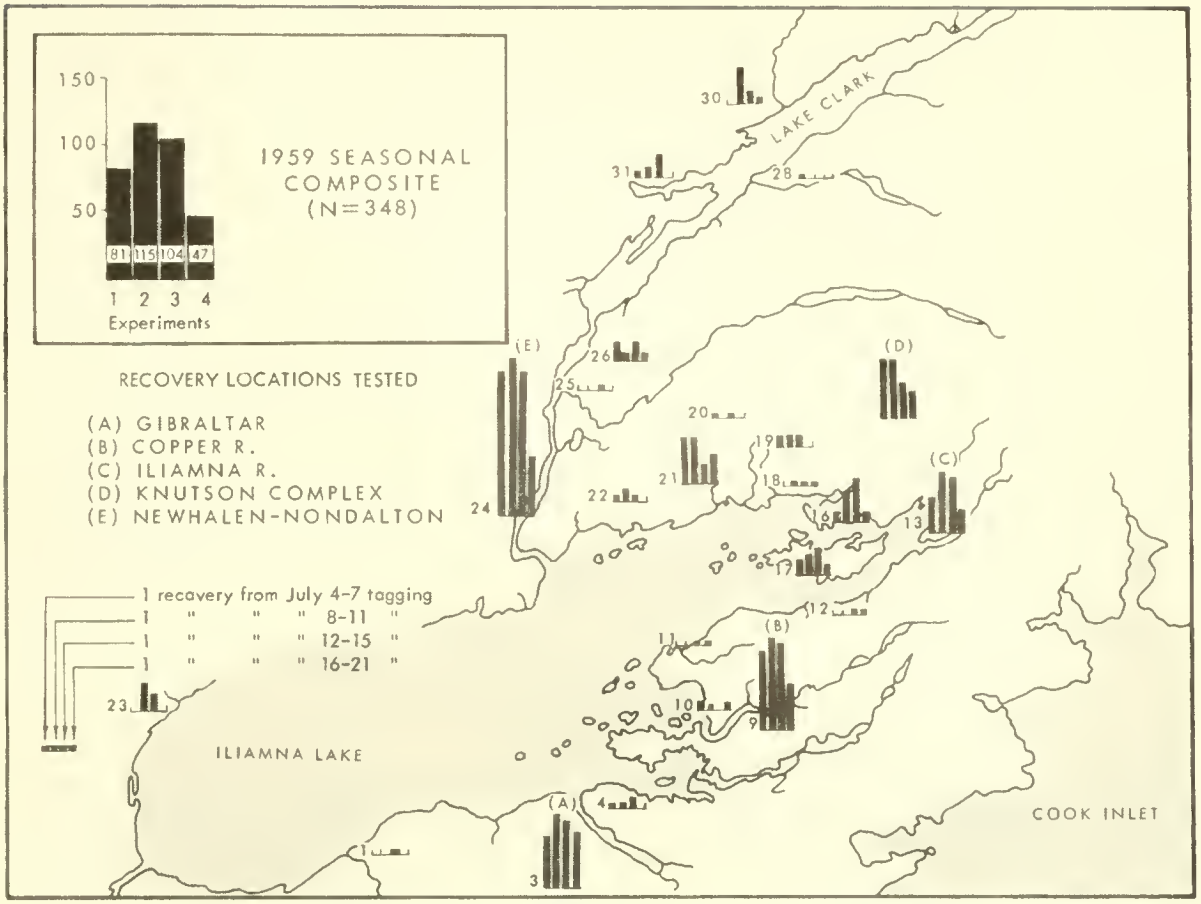


Figure 7.--Recoveries by experiment, 1959, Kvichak River system. For explanation of figure, see legend to figure 5.

vicinity. In view of these complications it was considered best to combine recoveries for several important spawning groups in the Knutson Bay area. Significantly, the group spawning on the beach in Knutson Bay is one of the largest and therefore most important in the system.

Newhalen-Nondalton recoveries are virtually all from personal-use fishing effort and do not represent well-defined groups. Tags were drawn principally from spawners destined for the Newhalen River and above, though some Newhalen village catches may include fish bound for points east of there.

It appears then that of the five recovery points tested, two, Copper and Iliamna Rivers, were represented by fish drawn from their respective spawning groups only. The Gibraltar River recoveries were representative of the group in that river though they were not exclusively from Gibraltar River fish. The recoveries in Knutson Complex were representative of fish of a fairly well-defined geographical region that includes important Knutson Bay. Newhalen-Nondalton represented a block of recoveries of indefinite origin above Iliamna Lake. Because of their heterogeneous representation, these Knutson Complex and Newhalen-Nondalton recovery points are not as valuable to the discussion as are Copper, Iliamna, and Gibraltar; but nevertheless they contribute to the evaluation of segregation in time of entry.

Table 5.--Comparison by tagging experiment of recoveries of marked red salmon at principal recovery points, Kvichak River system

Recovery area	1957 Experiments					1958 Experiments					1959 Experiments				
	1	2	3	4	All	1	2	3&4[1]	(4)	All	1	2	3	4	All
Gibraltar	14	21	20	33	88	32	7	29	(14)	68	9	14	12	9	44
Copper R.	15	24	13	15	67	12	4	5	(0)	21	13	18	16	8	55
Knutson	7	5	8	7	27	15	7	9	(2)	31	13	13	7	6	39
Newhalen-Nondalton	11	7	5	8	31	48	23	52	(18)	123	27	30	27	11	95
Iliamna R.						9	6	13	(6)	28	6	11	10	4	31
Combined	47	57	46	63	213	116	47	108	(22)	271	68	86	72	38	264
Total tagged	1,000	1,000	1,000	1,004	4,004	978	419	879	(352)	2,276	436	613	638	317	2,004
	Chi-square = 12.193 d. f. = 9 and p = 0.203					Chi-square = 8.436 d. f. = 8 and p = 0.400					Chi-square = 5.684 d. f. = 12 and p = 0.929				

[1] Grouped because of small returns from experiment 4.

Statistical Comparison for Iliamna Lake and Lake Clark

All Iliamna Lake recoveries combined and all recoveries in the Newhalen and above, also combined, are arranged by experiment in table 6 where they are headed simply, "Iliamna Lake" and "Lake Clark." Chi-square tests of the hypothesis of like recovery distributions in the two lakes yielded values p = 0.008 for 1957, p = 0.700 for 1958, and p = 0.613 for 1959 data. Clearly the 1957 distributions differed widely; 1958 and 1959 distributions were strikingly similar. It is apparent that only in 1957 was there marked segregation; more of the early salmon went to Lake Clark. It is now important to determine whether the segregation applied to the entire system above Iliamna Lake or merely to parts of it. This may be resolved by a process of elimination.

In figure 5 distributions at recovery points 25, 26, 27, and 28 involved small numbers of tags, apparently distributed similarly to the composite. These are not responsible for the low level of probability associated with the 1957 test. Newhalen-Nondalton recoveries have already been compared with important recovery points on Iliamna Lake. They were accepted as distributed in the same proportions, though with some reservation because the visual comparison showed contrast. The combined Gibraltar, Copper, and Knutson Complex recoveries were distributed in the same proportion as the remainder of Iliamna Lake recoveries grouped (p = 0.806), so no discrepancy was introduced by lumping all Iliamna Lake data. The cause of the low probability level associated with the test of Iliamna Lake data against all data from above Iliamna Lake appears then to be Kijik Lake.

In summary, no significant difference is apparent in the distributions to Iliamna Lake and Lake Clark in 2 of 3 years. The difference in 1957 appears positively associated with the Kijik spawning system. Kijik itself, while contrasting with the remainder of the system, is not clearly segregated. Its escapement data exhibit somewhat independent but also inconsistent timing and form, since they differed from the composite in a different way each year.

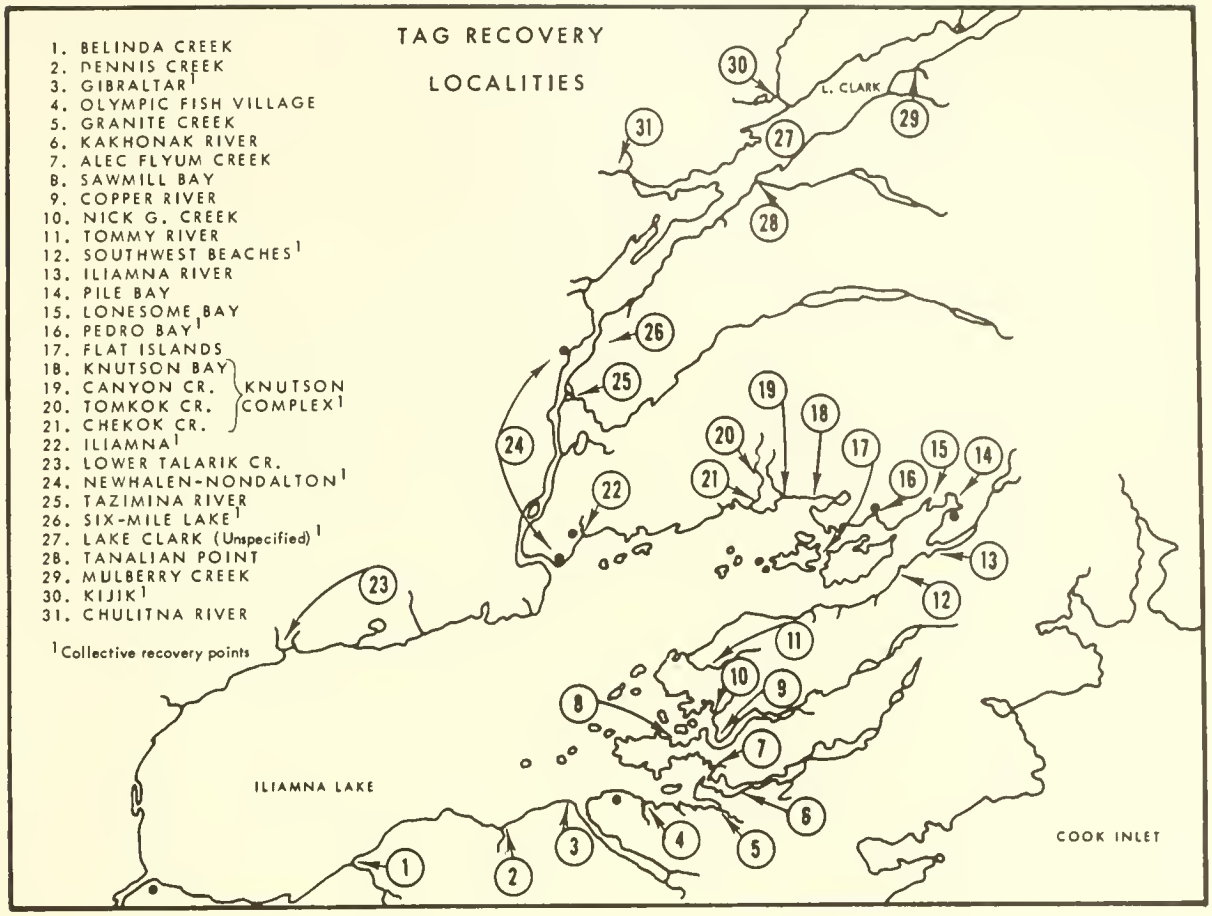


Figure 8.--Tag recovery locations, Kvichak River system.

Table 6.--Comparison by tagging experiment of Lake Clark recoveries with Iliamna Lake recoveries

Recovery area	1957 Experiments					1958 Experiments					1959 Experiments				
	1	2	3	4	All	1	2	3	4	All	1	2	3	4	All
Iliamna Lake	43	58	50	69	220	100	37	58	26	221	49	74	67	34	224
Lake Clark	23	10	8	14	55	81	30	50	30	191	32	41	37	13	123
Both	66	68	58	83	275	181	67	108	56	412	81	115	104	47	347
Total tagged	1,000	1,000	1,000	1,004	4,004	978	419	527	352	2,276	436	613	638	317	2,004
	Chi-square = 12.191 d. f. = 3 and p = 0.008					Chi-square = 1.426 d. f. = 3 and p = 0.700					Chi-square = 1.832 d. f. = 3 and p = 0.613				

SUMMARY AND CONCLUSIONS

Data are presented which show that there is little difference, if any, in the timing, distribution, and form of constituent spawning groups in the Kvichak River escapement. Red salmon in the Kvichak–Naknek fishery maintained their chronological order of appearance during their migration through the trunk river. Virtually without exception the pattern of recovery from individual spawning groups was similar to that of the escapement. Possible segregation of spawning groups in time of occurrence in the fishery may therefore be studied in the escapement past Igiugig on the upper Kvichak River.

Although segregation of groups by time of occurrence appears impossible, some groups that spawn in deep or glacial waters may have been missed on the spawning grounds. Koo and Smith (1960) concluded that differences in fresh-water age composition between samples from the Kvichak River and those from the spawning grounds were due to difficulties in obtaining representative samples from the spawning grounds. Because this may have been caused by the omission of certain groups on the spawning grounds, they may have also been missed during tag recovery. Until all spawning grounds in the system are delineated, this problem will persist; though in view of the nature of groups studied here, there is little likelihood that missing groups would be segregated in time of passage into the system.

Distinctive features of spawning groups as they pass Igiugig, and hence as they occur in the fishery, are far too vague to be of value in managing the runs. Tests of high sensitivity in the future may provide a means of differentiating at least the larger groups while they are in the fishery.

For the present, those responsible for managing the runs must strive for population levels most desirable for the system as a whole.

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William F. Thompson, Professor Emeritus, and first Director of the Fisheries Research Institute provided guidance during the first 2 years of this study. C. Dale Becker, John R. Gilbert, Donald R. Heinle, Orra E. Kerns, Jr., Lloyd A. Phinney, and D. W. Linn have contributed greatly to the accomplishments reported here, and Oren B. Hudson of Iliamna, Alaska, has consistently and unselfishly given his time and service.

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